

## Introducing chemical recycling: Plastic waste becoming a resource

*“Every year, Europeans generate 25 million tonnes of plastic waste, but less than 30% is collected for recycling” states the 2018 European Plastics Strategy.*

The Green Deal is at the heart of the EU’s ambitions of becoming climate neutral. To meet the ambitious European objectives, much more waste plastic needs to be recycled and a broader range of markets need to be served with plastic products containing recycled content. In this respect Cefic highlights the potential of chemical recycling of plastic waste. Transitioning from a linear economy to a sustainable circular economy using innovative technologies is a key opportunity for Europe and its industries.

### Background

The recycling<sup>1</sup> rate for glass, paper and metal today in the EU is well over 70%. Combinations of different recycling processes, techniques and solutions are in place to achieve these recycling rates. Similarly, in the development of a circular economy for plastics a combination of complementary options will be required to achieve high recycling rates for plastics.

Chemical recycling can fill a void in the plastics recycling loop, conserve valuable resources, and contribute to the creation of low carbon circular economy. Chemical recycling **complements** other plastic recycling options like mechanical and dissolution recycling. It is capable of processing contaminated and/or mixed plastic waste which would otherwise end up in incineration (with or without energy recovery) or landfill. Chemical recycling technologies allow use of plastic waste as feedstock to produce new chemicals and plastics. The quality of the latter is equivalent to those produced from virgin resources, allowing use in high-quality applications such as food contact and food packaging. An added benefit is the potential of chemical recycling to capture and separate the so-called legacy chemicals and substances of very high concern (SVHC) that can be present in end-of-life plastic.

Chemical recycling is not yet a widely deployed option for the recycling of plastic waste. Scale-up requires innovation, harmonised policies, recycling-chains and clear pathways to “valorise” plastic waste that is currently incinerated, landfilled or wasted. The involvement of the entire value chain in combination with a transnational policy framework are key in this respect.

**To ensure the scale up and full deployment of chemical recycling, the industry is operating under the following guiding principles:**

- **Increase collaboration and work in partnerships to boost innovation and investments**
  - Innovation and Research & Development (R&D) across innovation ecosystems and along the value chains creates the opportunity to address, amongst others operability, impurities – removal of additives / legacy chemicals / substances of very high concern (SVHCs) –

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<sup>1</sup> Common recycling definition: Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations. [EU Directive 2008/98/EC of 19 November 2008 on waste, Article 3 \(17\)](#)

- process yield, human and environmental risk assessment, and development of new (e.g. CO<sub>2</sub> neutral) processes.
- Formation of value chain partnerships and commitments enable investment into scale-up of chemical recycling technologies to demonstration and commercial scale.
- **Increase transparency and develop uniform standards for a mass balance approach.**
  - Adoption of a mass balance approach by the plastic value chains in the tracing and attributing credits of chemically recycled plastics.
  - Transparent certification by an independent party at each step of the value chain.
  - Development of standards which include clear and credible rules on feedstock qualification, mass balance calculation, and the use of appropriate product claims.
- **Further develop quality standards for sorted/pre-treated plastic waste** to provide clarity, consistency and transparency across Europe – if not globally – from which (new) business cases can be developed. Chemical recycling process types, food contact and REACH legislation, amongst others, should be considered in the development of these standards.
- **Life Cycle Assessments (LCA)** to measure environmental impacts along the life cycle of products. Conduct LCA studies to compare plastics from chemically recycled feedstock to plastics made from virgin fossil resources or alternative feedstocks.

**We invite policymakers to integrate into their decisions the following key enablers, necessary for ensuring the scale up and full deployment of chemical recycling and dissolution<sup>2</sup> recycling technologies:**

- **An enabling policy framework.** A policy framework that looks beyond the traditional boundaries of regions and Member States and offers an open investment environment and a competitive economic model.
  - Ensure a level playing field with mechanical recycling of plastic waste. Chemical recycling falls under the recycling definition in [EU Directive 2008/98/EC](#), except when it leads to reprocessed products in fuel.
  - Develop a clear and harmonised recycling-rate and recycled-content rule throughout the EU, building on the common recycling definition in the [EU Directive 2008/98/EC](#).
  - Create legal acceptance of a mass balance approach for chemical recycling based on a recognised standard when implementing or amending legislation.
  - Public sector co-funding to accelerate R&D partnerships and address the higher risk areas (e.g. bridging the valley of death, coordinating innovation across the whole value chain).
- **Access to feedstock.** For the operation of chemical recycling plants it is necessary to have a stable, continuous supply of plastic waste.
  - Ensure an open, single market for plastic waste. This can be achieved with a “fit for purpose” and harmonised approach for the shipment of plastic waste for use in recycling facilities within Europe and potentially also imported into Europe to help other regions in the creation of low carbon circular economy for plastics.

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<sup>2</sup> *Cefic definition: Dissolution recycling* Is a process in which the plastics is dissolved in a suitable solvent, in which a series of purification steps are undertaken to separate the target polymer/polymers from additives and other added materials (e.g. e.g. fibers, fillers, colorants) and contaminants. The resulting output is the recovered polymers, which remain largely unaffected by the process and can be reformulated into plastics. This process may also enable the recovery of other valuable components of the plastic.

## Appendix I: Important clarifications about chemical recycling

### Introduction

This paper describes the potential contribution that chemical recycling can make to the development of a circular economy for plastics and the key requirements to allow that to happen. The paper will be updated regularly as chemical recycling grows and develops over time.

### What is chemical recycling?

*Cefic definition:* Feedstock recycling, also known as chemical recycling, aims to convert plastic waste into chemicals. It is a process where the chemical structure of the polymer is changed and converted into chemical building blocks including monomers that are then used again as a raw material in chemical processes.

Feedstock recycling includes processes such as gasification, pyrolysis, solvolysis, and depolymerisation, which break down plastic waste into chemical building blocks including monomers for the production of plastics.

### What are the benefits of chemical recycling?

- **Gives value to otherwise unused plastic waste.** Today suitably sorted plastics are mechanically recycled. This means that a large quantity of plastic waste, the kind that is contaminated or mixed, is still being incinerated, landfilled or exported. Chemical recycling enables recycling of contaminated and/or mixed plastic waste that cannot be recycled through mechanical recycling. An added benefit is the potential of chemical recycling to address – and separate – the so-called legacy chemicals and substances of very high concern (SVHC) that can be present in end-of-life plastic after multiple years of use.
- **Produces equivalent quality plastics to virgin feedstock.** With chemical recycling end-of-life plastics are recycled back into the production of new chemicals and plastics with an equivalent quality to those produced from virgin feedstock. This recycled plastic can therefore be used in high-quality applications such as food contact and food packaging.
- **Reduces the use of fossil feedstock** to produce plastics, since chemically recycled plastics can be re-used as feedstock for new plastics.
- **Reduction of CO<sub>2</sub> emissions.** Chemical recycling can eliminate the emissions associated with incineration and energy recovery.

### Why the chemical industry?

The chemical industry is actively engaged in developing, partnering, assessing and piloting chemical and dissolution recycling technologies (see Appendix II for some recent announcements). In its Mid-Century Vision<sup>3</sup>, the European chemical industry is seen at the centre of Europe's circular economy. By establishing chemical and dissolution recycling, the chemical industry becomes an enabler for sustainable value chains and helps these value chains meet their plastic waste recycling objectives and become fully circular.

### What are the challenges?

Chemical recycling requires involvement of the full value chain and a policy framework that looks beyond the traditional boundaries of regions and Member States.

To be successful, chemical recycling must be supported by a holistic enabling policy framework, an open investment environment and a competitive economic model.

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<sup>3</sup> 'Molecule Managers – A journey into the Future of Europe with the European Chemical Industry' - Cefic's Mid-Century Vision report, June 2019 < [link](#) >

Chemical recycling processes such as gasification, pyrolysis, solvolysis, and depolymerisation exist at a demonstration level and smaller industrial size and require further research and development efforts as well as subsequent commercialisation (the Technology Readiness Level varies for different processes)<sup>4</sup>.

For the scale-up the following needs to be considered:

- Integration into existing chemical plant operations, either as feedstock or as monomer.
- Consistency of plastic waste input quality from the collection and sorting processes.
- Development of the business case for chemical recycling of plastic waste.

## How can the challenges be addressed?

### By the value chain

- **Increase collaboration and work in partnerships to boost innovation and investments**

The successful development of these technologies requires collaboration across the innovation ecosystem (universities, Research and Technology Organisations, private sector) and along the value chains. Partnerships are an effective instrument to 1) share knowledge and information in terms of technology development and needs along the value chain, and 2) create a win-win cooperation. Public sector co-funding accelerates the formation of R&I project partnerships, specifically if the co-funding is directed towards the higher risk areas (e.g. low TRL technology development, or coordinated innovation needs across the whole value chain).

Innovation requirements for chemical recycling technologies are for instance defined by SusChem<sup>5</sup>, the European Technology platform for Sustainable Chemistry and can be summarised to:

<i>Input</i>	Precision and consistency of the plastic waste collection and sorting processes.
<i>In process</i>	Addressing operability, impurities – removal of additives / legacy chemicals / SVHCs – process yield, and development of new processes, e.g. synthetic biological, CO <sub>2</sub> neutral.
<i>Output</i>	Purification technologies.

Recycling of specialty, or advanced material products (e.g. composites and fiber reinforced), will require the development of technology options today only available at lab- or pilot scale level. The development of continuous processes towards crude monomers from solvolysis and depolymerisation needs efforts.

- **Transparency and uniform standards for a mass balance approach**

The chemical industry uses a small set of raw materials or feedstocks to produce tens of thousands of products. To fully unlock the circular economy potential of the chemical sector, a new approach is needed. A mass-balance method offers a workable set of rules to ensure the attribution of recycled feedstock into new products.<sup>6</sup>

With the logistics and operations in the chemical industry it is impossible to ‘track and trace’ the pathway of each feedstock-molecule to product-molecule. A mass balance approach is considered to be one of the best ways to promote the use of circular feedstock. Like proven approaches for instance in timber, cacao and coffee, mass balance can enable a credible and transparent traceability between feedstock input and product output, and along the value chain to the producer of a final article.

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<sup>4</sup> ‘A circular economy for plastics; Insights from research and innovation to inform policy and funding decisions’ - EU Commission, March 2019 < [link](#) >

<sup>5</sup> ‘Plastics strategic research and innovation agenda in a circular economy’ – SusChem, 2018 < [link](#) >

<sup>6</sup> ‘Enabling a circular economy for chemicals with the mass balance approach’ – Ellen MacArthur Foundation < [link](#) >

Mass balance can be used for any chemical recycling process producing feedstocks like naphtha, syngas, oil or monomers. To leverage the benefits and traceability while remaining pragmatic about the implementation, Cefic recommends:

- Adoption of a mass balance approach in the tracing of chemically recycled plastics.
- Transparent certification by an independent party at each step of the value chain.
- Development of a standard which includes clear and credible rules on feedstock qualification, mass balance calculation and the use of appropriate product claims.

- **Further develop quality standards for sorted/pre-treated plastic waste**

Efficient recycling of any material goes hand in hand with proper collection and reliable sorting of waste materials. While well-sorted and defined plastic waste streams are used for mechanical recycling, chemical recycling has a broader tolerance, ranging from homogenous but contaminated streams to mixed plastic waste streams. The two types of recycling options address very different waste streams and enable different products containing recycled plastic content.

Quality standards for sorted plastic waste will be further developed to provide clarity, consistency and transparency across Europe – if not globally – from which (new) business cases can be developed. Chemical recycling process types, food contact and REACH legislation amongst others should be considered in the development of these standards.

- **Life Cycle Assessment (LCA)** is a broadly accepted method to measure environmental impacts along the whole life cycle of a product. As more examples of the circular use of chemically recycled plastic products become available, LCA studies should be initiated to compare chemical recycling of plastics to plastic from virgin fossil resources or alternative feedstocks. A report by Material Economics<sup>7</sup> indicates that chemically recycled plastics have a lower carbon footprint than plastics made from fossil resources. The study also acknowledges the reduced fossil depletion when using the carbon again.

### By EU policymakers and decision makers

- **Access to feedstock**

Cefic calls for an open single market for plastic waste by taking a logical and harmonised approach to shipping plastic waste for use in recycling facilities within Europe and possibly also imported into Europe.

For the operation of chemical recycling plants, the following factors are deemed to be particularly important:

- The quantity of sufficient quality of plastic waste
- The stable and continuous supply of plastic waste, and
- The size of the required collection area (region or beyond) for plastic waste

Insufficient quantities of plastic waste collected and sorted could curtail the needed investments in chemical recycling. A wider sourcing area could create transboundary shipments of plastic waste, which could be hampered by national legislation, the **Basel Convention**, and create administrative challenges.

Eco-modulation schemes, like Extended Producers Responsibility (EPR) and others, could be used to establish the required collection and sorting infrastructure to enable the required continuous flow of plastic waste to chemical recycling plants.

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<sup>7</sup> 'The circular economy, a powerful force for climate mitigation' – Material Economics, 2018 < [link](#) >

- **An enabling regulatory framework**

An enabling regulatory framework will be essential to grow chemical recycling to scale in Europe. Cefic calls for:

1. **Harmonised definitions and standards:**

- a. **Maintain a technology-neutral** definition of recycling in the European waste legislation and evolving legislation, including comitology. Provide clear harmonised rules to guarantee uniform application in all Member States (implementing regulation and national energy & climate plans).
- b. Create a **level playing field** between different recycling options in the calculation of recycling targets and recycled content.
- c. Create legal acceptance for **mass balance** standard calculation of targets and recycled content.
- d. Use the European **waste hierarchy** and keep the different recycling options at a same level. Cefic supports the Waste Hierarchy definition and approaches<sup>8</sup> and calls for all forms of recycling of plastic waste to be kept at the same level and keep the legislative framework technology-neutral in this respect.
- e. Apply the **same incentive schemes** for all recycling options (e.g. the application of EPR fees and their modulation for recyclable plastics or plastics with recycled content).

2. Avoiding **legislative hurdles** for chemically recycled products in food contact applications.
3. Ensuring that **transport of plastic waste** for recycling is enabled within the European market
4. Putting an **end to landfilling** of plastic waste.

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About Cefic:

Cefic, the European Chemical Industry Council, founded in 1972, is the voice of large, medium and small chemical companies across Europe, which provide 1.2 million jobs and account for 16% of world chemicals production.

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<sup>8</sup> EU Directive 2008/98/EC of 19 November 2008 on waste, Article 4 (1) <[link](#)>

## Appendix II: Chemical recycling; a selection of announcements

*The transition from a linear economy to a sustainable circular economy is one of the key opportunities for Europe and its industries. Chemical recycling of end-of-life plastics can fill a key gap in the recycling loop and further advance plastics recycling. Chemical recycling is not widely deployed today and will require a number of developments in order to grow. These include the further progress of technology and business cases. A collection of recent announcements from the chemical industry in this respect:*

### Arkema

Arkema is a partner in the MMAtwo project (kick-off October 2018) supported by a 6.6 M€'s funding from the European Union Horizon2020 Research and Innovation programme. MMAtwo collaborative consortium gathers 13 partners from 6 different countries and will develop a new and innovative process to recycle post-industrial and end-of-life Polymethylmethacrylate (PMMA) waste into Second Generation MethylMethAcrylate (MMA) raw material. For more information: [Link](#) [January 2019]

### BASF

BASF announced its ChemCycling project in 2018 with the aim to process recycled raw materials obtained from plastic waste in its production Verbund. Together with customers from various industries, BASF has already produced first prototypes based on chemically recycled plastic waste – including food packaging for which particularly high quality and hygiene standards apply. BASF announced in October 2019 to invest €20 million into Quantafuel, a specialist for pyrolysis of mixed plastic waste and purification of pyrolysis oil, headquartered in Oslo, Norway. For more information: [Link](#) [October 2019]

### Borealis

In line with the vision that post-consumer plastic waste is too valuable for single use, OMV and Borealis are exploring the potential for synergies in the OMV ReOil innovation project. The OMV ReOil pilot plant has been fully integrated into the refinery and has a processing capacity of up to 100 kilograms per hour, equivalent to 100 litres of synthetic crude. This crude is processed either into feedstock for the plastics industry or fuel and creates a resource-efficient circular economy. For more information: [Link](#) [May 2019]

### BP

In October 2019, BP announced that it aims to prove its Infinia technology on a continuous basis at a \$25 million pilot plant in Naperville, US, which it plans to construct in 2020. In December 2019, BP joined forces with leading companies operating across the polyester packaging value chain to accelerate commercialisation. BP Infinia is an enhanced recycling technology designed to turn opaque and difficult-to-recycle PET plastic waste into recycled feedstocks that can be used to make new, high-quality PET plastic packaging again and again, with no loss in quality. For more information: [Link](#) [December 2019]

### Covestro

Covestro is partner of the PReSmart research consortium, which began its work in 2019 and is researching ways to improve the recycling of polyurethane plastics and to develop a circular product cycle for these materials. In this context, Covestro is investigating the feasibility of a short-term scale-up from laboratory scale to semi-industrial level. In 2019, Covestro also became member of the Consortium for a Circular Carbon Economy in North Rhine-Westphalia. The consortium works intensively on researching the interconnection of the local waste, chemicals and energy sectors and to create chemical products from raw materials like plastic waste.

For more information: PReSMART: [Link](#) [January 2019] Consortium: [Link](#) [September 2019]

### Dow

Announced an agreement with the Fuenix Ecogy Group, based in Weert, The Netherlands, for the supply of pyrolysis oil feedstock, which is made from plastic waste. The feedstock will be used to produce new polymers at Dow's production facilities in Terneuzen, The Netherlands. The polymers produced from this pyrolysis oil will be identical to products produced from traditional feedstocks, and as such, they can be used in the same applications, including food packaging. For more information: [Link](#) [August 2019]

## **EASTMAN**

Eastman is revolutionising recycling on the molecular level. Using multiple advanced chemical recycling technologies, Eastman can recycle almost any plastic waste, including textiles, an infinite number of times, creating a true circular solution. In 2019, Eastman began chemically recycling a broad set of plastics at commercial scale, and is moving rapidly to incorporate increasing quantities of waste plastics into its products. The recycled materials are indistinguishable from those materials produced from fossil feedstocks, and have a significantly lower carbon footprint. In 2020, the company will commercialize materials with recycled content.

For more information: [Link](#) [October 2019]

## **Evonik**

In the project “Rheticus” funded by Germany's Federal Ministry of Education and Research (BMBF, FKZ 03SF0548A and 03SF0574A) Evonik and Siemens co-create a test plant for the production of specialty chemicals out of CO<sub>2</sub>. Siemens' part is the production of syngas by using carbon dioxide (CO<sub>2</sub>), water and electricity from renewable sources. Evonik converts the syngas in a bio-tech process directly towards specialty chemicals e.g. for the plastics industry. The required syngas for that bio-tech process may also come directly from gasification of mixed and soiled plastics-containing waste so that the carbon is kept in the value chain by that chemical recycling process. For more information: [Link](#) [October 2019]

## **INEOS**

INEOS Styrolution announced a collaboration with Indaver, driving forward chemical recycling for polystyrene in Europe. The collaboration between the two companies aims at taking advantage of the recyclability of polystyrene to convert post-consumer waste into valuable resources: [Link](#) [July 2019]

INEOS Styrolution also collaborates with Agilyx. Together with Trinseo, they plan a recycling plant under the umbrella of SCS in Europe, [Link](#) (July 2019), in the U.S. Styrolution plans a recycling plant with Agilyx in Channahon, Illinois. For more information: [Link](#) [December 2019]

## **LyondellBasell**

Announced the cooperation with Karlsruhe Institute of Technology (KIT) to advance the chemical recycling of plastic materials and assist the global efforts towards the circular economy and plastic waste recycling needs. The focus of the venture is to develop a new catalyst and process technology to decompose post-consumer plastic waste, such as packaging into cracker feedstock or monomers for reuse in polymerisation processes.

For more information: [Link](#) [July 2018]

## **Neste**

Neste has pledged to work towards chemical recycling of more than one million tons of plastic waste annually from 2030 onwards. Chemical recycling can increase plastics' recycling rate by complementing mechanical recycling by utilising waste plastic streams that currently have no or low value in recycling. Neste announced its partnership with Remondis to develop chemical recycling of plastic waste and its collaboration with Ravago to enable the achievement of its ambitious goal. For more information: [Link](#)

## **Repsol**

Repsol achieves another important milestone in its commitment to boost the circular economy and stands as a pioneer in the production of certified circular polyolefins, which use plastic waste as raw material. In 2015, Repsol experimentally began to feed oil from chemically recycled plastic waste, leading the implementation of plastic waste chemical recycling on an industrial scale. Repsol has obtained ISCC PLUS certification for its complex in Puertollano for the first tonnes of circular polyethylene and polypropylene that are already commercially available to its customers in Europe. For more information: [Link](#) [October 2019]

## **SABIC**

SABIC's certified circular polymers are being produced using a pyrolysis oil feedstock from the recycling of mixed plastic waste. SABIC is introducing this alternative feedstock into its Chemelot production site at Geleen in The Netherlands. The resultant certified circular polymers are to be supplied to branding leading customers - Unilever, Tupperware Brands, Vinventions and Walki Group - to use in the development of pioneering, high quality and safe consumer goods or packaging for food, beverage and personal care products.

For more information: [Link](#) [July 2019]



## Shell

Shell announced it has successfully made high-end chemicals using a liquid feedstock made from plastic waste. The technique, known as pyrolysis, is considered a breakthrough for hard-to-recycle plastics and advances Shell's ambition to use one million tonnes of plastic waste a year in its global chemicals plants by 2025.

For more information: [Link](#) [November 2019]

## Total

Total has joined Citéo, Recycling Technologies, Nestlé and Mars in a consortium of players from across the plastic packaging value chain to examine the technical and economic feasibility of recycling complex plastic waste which are currently considered non-recyclable and are therefore either incinerated or disposed of in landfills. This project will contribute to Total's ambition to produce 30% recycled polymers by 2030.

For more information: [Link](#) [December 2019]

## Versalis

Versalis launched Hoop™, a project for the development of a new chemical recycling technology. To this end Versalis signed a joint development agreement with Italian engineering company S.R.S., which owns a pyrolysis technology that will be further developed to be able to transform mixed plastic waste, that cannot be mechanically recycled, into raw material to produce new virgin polymers. Versalis will leverage its technological and industrial expertise to build a first plant with a capacity of 6,000 tonnes per year in its Mantova site, with a view to progressively scaling-up. For more information: [Link](#) [February 2020]

## PolystyreneLoop Project

The PolyStyrene Loop Cooperative is a non-profit organisation, initiated by ICL and Synbra Technology. The Cooperative has 70+ members and supporters from 18 EU countries, representing the entire polystyrene foam value chain. EPS/XPS construction waste coming from buildings that were insulated with EPS/XPS before August 2015 all contain a now banned Persistent Organic Pollutants (POP) substance, rendering all this EPS/XPS unrecyclable. Polystyrene Loop will separate Hexabromocyclododecane (HBCD) and will recycle polystyrene beads (PS) compliant to the POP regulation described in the Basel Convention. The separated HBCD will be safely destroyed and further treated in the Bromine Recovery Unit based at ICL allowing the recovery of elemental bromine. Members of the cooperative will take the 100% recycled PS and will use it in construction applications, as feedstock for extrusion of EPS beads, or via continuous XPS foaming. The bromine is used to produce new flame retardants in the same application and via chemical recycling closing the loop for bromine.

For more information: [Link](#) [December 2019]

The project is supported by the EU through the LIFE Financial instrument Environmental and Governance Program LIFE 16/ENV/NL/000271